Excitonics Based on Carbon Nanomaterials: a Pathway Toward Low-Power, High-Speed, and Radiation-Hard Computation

Completed Technology Project (2011 - 2015)

Project Introduction

Power management has emerged as a critical issue that is threatening continued scaling in high-performance metal "oxide" semiconductor (CMOS) technology. In particular, charge-based power dissipation is forcing designers to reduce computing performance to mitigate power consumption. Additionally, radiation-induced damage in CMOS field-effect transistor (FET) circuits, which is especially detrimental in military and space electronics applications, has prompted a search for more radiation-hard materials and technologies. Thus, research efforts are focusing on the development of novel, non-FET logic switching devices that are low-power and radiation hard. Due to their zero net charge, excitons (i.e., bound electron-hole pairs) are a focus of continuing research because they have the potential to be utilized for low-power, high-performance switching devices. One-dimensional (1D) carbon-based nanomaterials (e.g., carbon nanotubes and graphene nanoribbons) are a promising platform for these exciton-based devices because they have large exciton binding energies (> 0.1 eV), which could allow these devices to operate at room temperature. Additionally, 1D carbon nanomaterials also possess long radiative lifetimes, can be generated electrically and/or optically, and are inherently radiation-hard. Hence, these excitonic devices have the potential to be the low-power, high-switching, and radiation tolerant nanoelectronic devices necessary to further space exploration. This program will explore, analyze, and optimize electrical generation of excitons, exciton lifetime and stability, exciton transport, and exciton-exciton interactions in carbon-based nanomaterials. Through the use of high purity carbon-based nanoelectronic materials, radiation-hard self-assembled nanodielectrics (SANDs), and integrated optical spectroscopy and scanning probe microscopy we will elucidate the fundamental science and device potential for excitons in low-power, high-performance nanoelectronics for space applications. Specific research thrusts of this project include: Preparing monodisperse carbon nanotubes and graphene nanoribbons via Density Gradient Ultracentrifugation (DGU). Integrating SANDs into device geometries that will enhance exciton generation in carbon-based nanomaterials. Probing and characterizing excitonic phenomena using near-infrared scanning photocurrent microscopy

Anticipated Benefits

Power management has emerged as a critical issue that is threatening continued scaling in high-performance metal "oxide" semiconductor (CMOS) technology. In particular, charge-based power dissipation is forcing designers to reduce computing performance to mitigate power consumption. Additionally, radiation-induced damage in CMOS field-effect transistor (FET) circuits, which is especially detrimental in military and space electronics applications, has prompted a search for more radiation-hard materials and technologies. Thus, research efforts are focusing on the development of novel, non-FET logic switching devices that are low-power and radiation hard.

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Table of Contents

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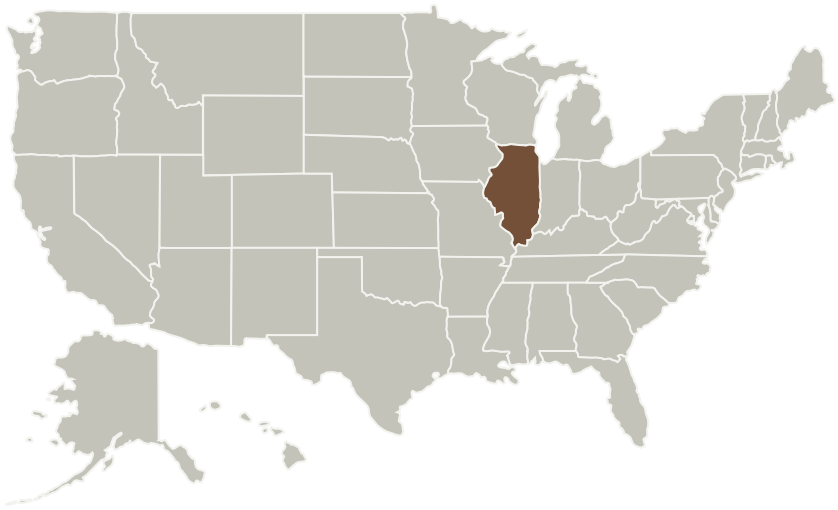
Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
Northeastern University(NEU)	Supporting Organization	Academia	Boston, Massachusetts

Primary U.S. Work Locations
Illinois

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

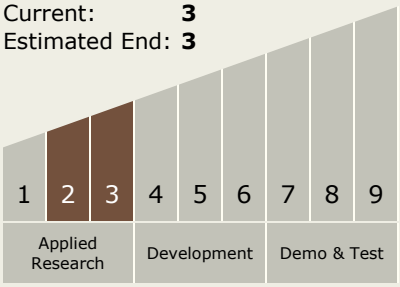
Mark Hersam

Co-Investigator:

Heather N Arnold

Technology Maturity (TRL)

Start: **2**
Current: **3**
Estimated End: **3**



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Images

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Project Image Excitonics Based on Carbon Nanomaterials: a Pathway Toward Low-Power, High-Speed, and Radiation-Hard Computation
(https://techport.nasa.gov/image/1764)

Project Website:

https://www.nasa.gov/directorates/spacetech/home/index.html

Technology Areas

Primary:

- TX12 Materials, Structures, Mechanical Systems, and Manufacturing
  - TX12.1 Materials
    - TX12.1.6 Materials for Electrical Power Generation, Energy Storage, Power Distribution and Electrical Machines